



# Mercury in the Everglades: Causes, Consequences, Correctives

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# 1. Mercury: what is it?

Mercury (**Hg**) is a highly toxic chemical element - a metal, that in pure form at room temperature, is a dense, silver liquid.

It occurs generally in very minute quantities in the Earth's crust throughout the world.

**Hg** is an abbreviation for hydragyrum; Latin for "liquid silver".



Elemental  
mercury





Shadow of  
mercury vapor

Flask of mercury

Because mercury can both evaporate into air, and, dissolve into water, it cycles between land, the atmosphere, lakes, and oceans.

## 2. How does Hg enter the environment?

Hg emissions to the atmosphere are very often the dominant source of Hg to waterbodies

### Natural emissions ~33%

- Volcanoes
- Degassing from Hg-rich areas
- Revolatilization

### Anthropogenic (human) ~67%

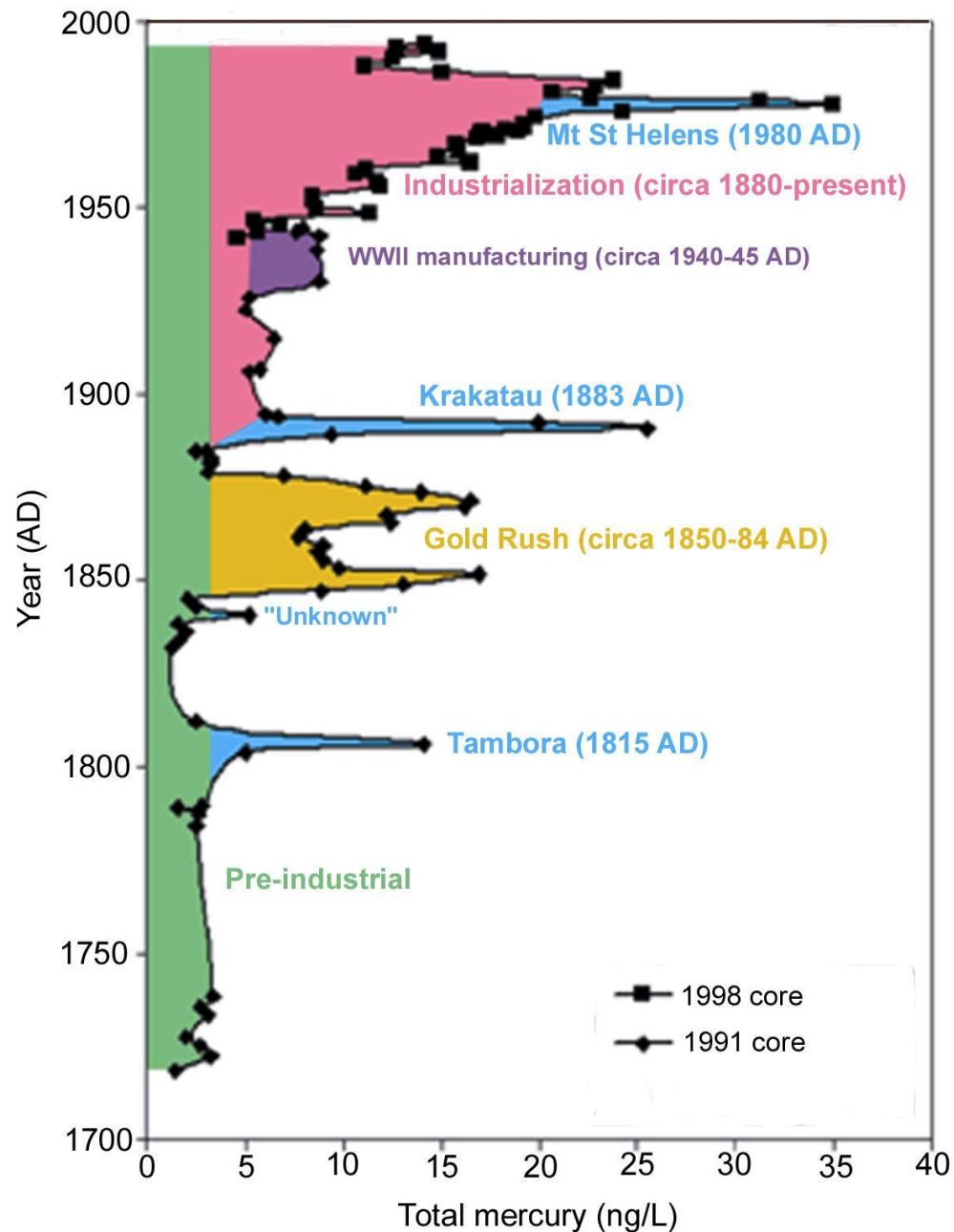
- Fossil fuel power plants
- Waste incinerators (municipal & medical)
- Chlor-alkali plants
- Cement manufacturing
- Phosphate production
- Iron-steel production
- Non-ferrous metal production
- Sewage sludge Incinerators
- Revolatilization

(Schroeder and Munthe, 1996; Pacyna and Pacyna, 2002)



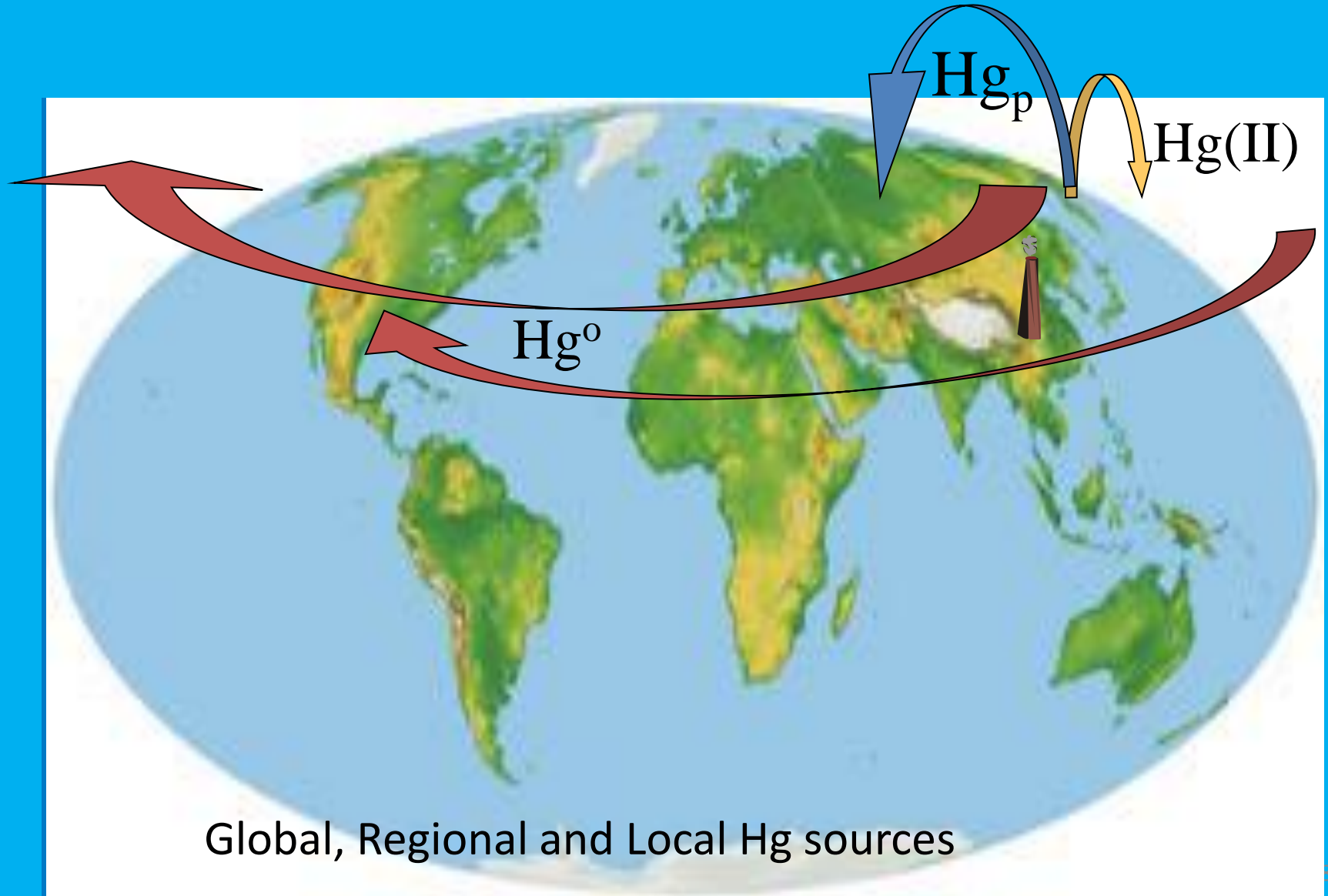
**Ice core  
record of  
mercury  
accumulation  
- Fremont  
Glacier, WY**

Figure 2



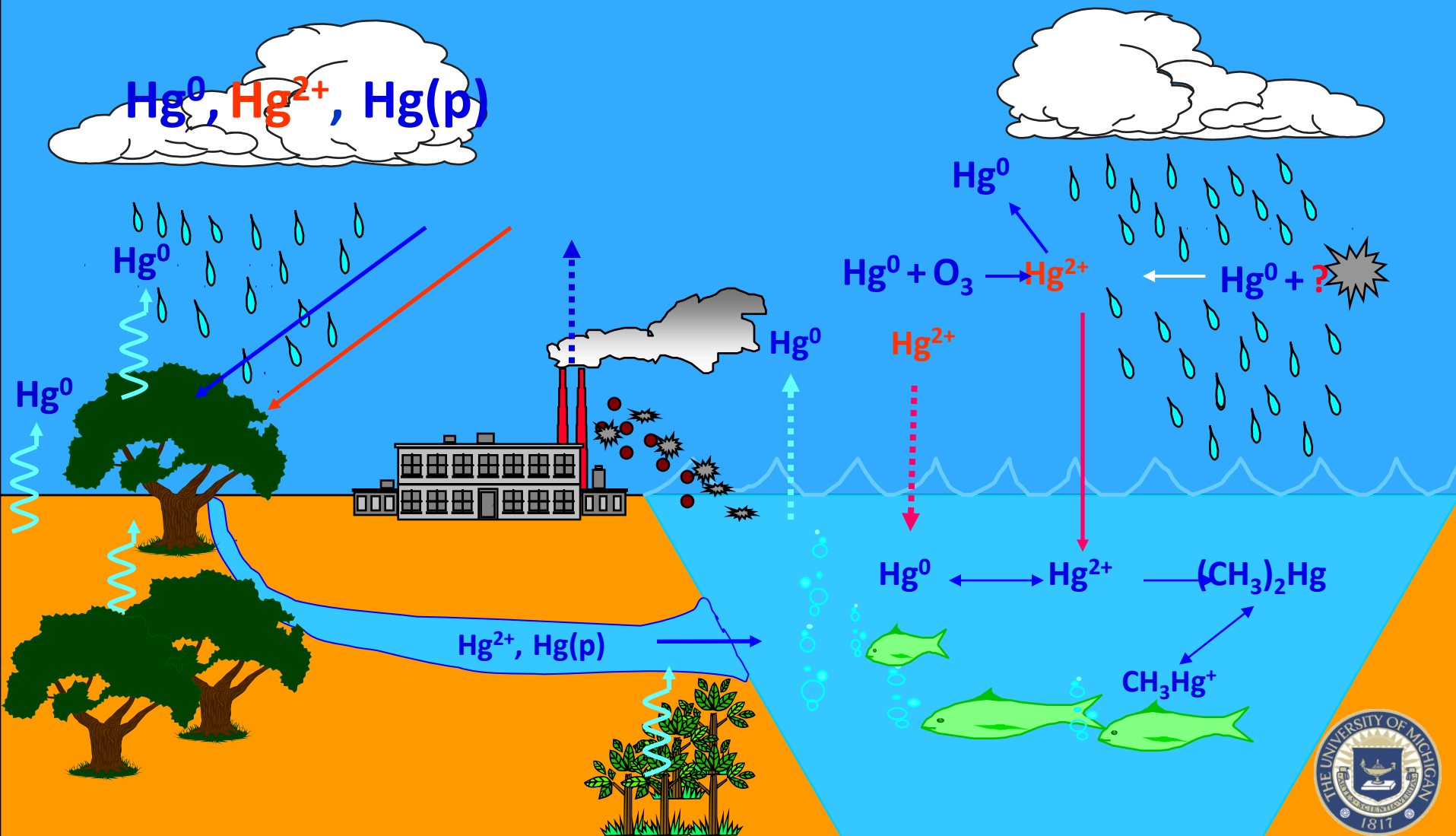
### 3. How does Hg get into aquatic ecosystems?

#### Atmospheric Hg Cycle –





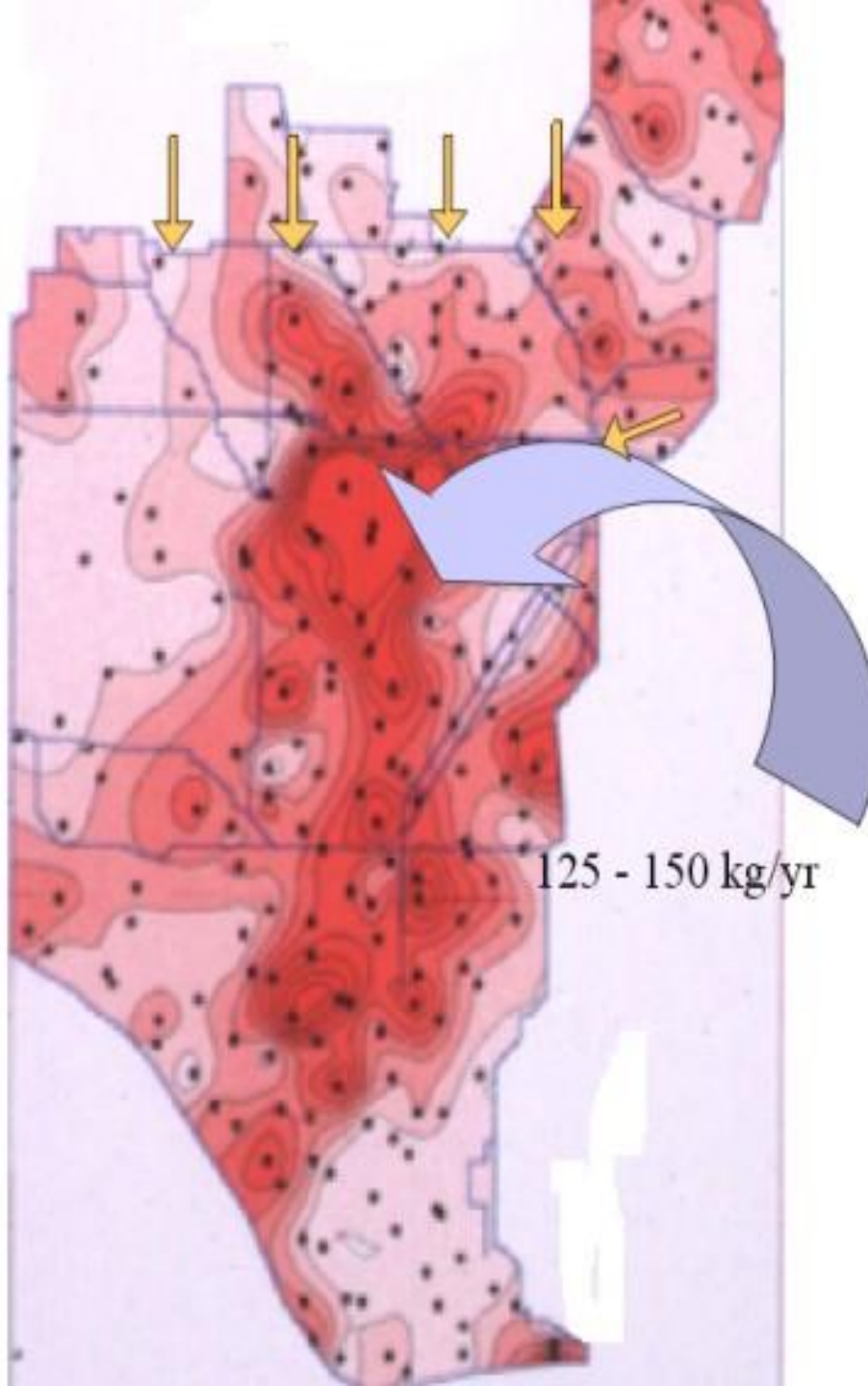
# Mercury Cycling in the Biosphere



# 4. Discovery of the Everglades Hg problem

## Mercury ~1990 THE PROBLEM



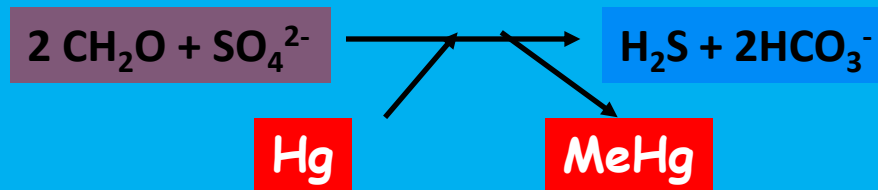


## 5. How does Hg get into the Everglades?

~ 98 % of Hg input  
to the Everglades is  
atmospherically  
sourced  
(falling as dust or in rain)

## 6. How is mercury (Hg) converted to methylmercury (MeHg)?

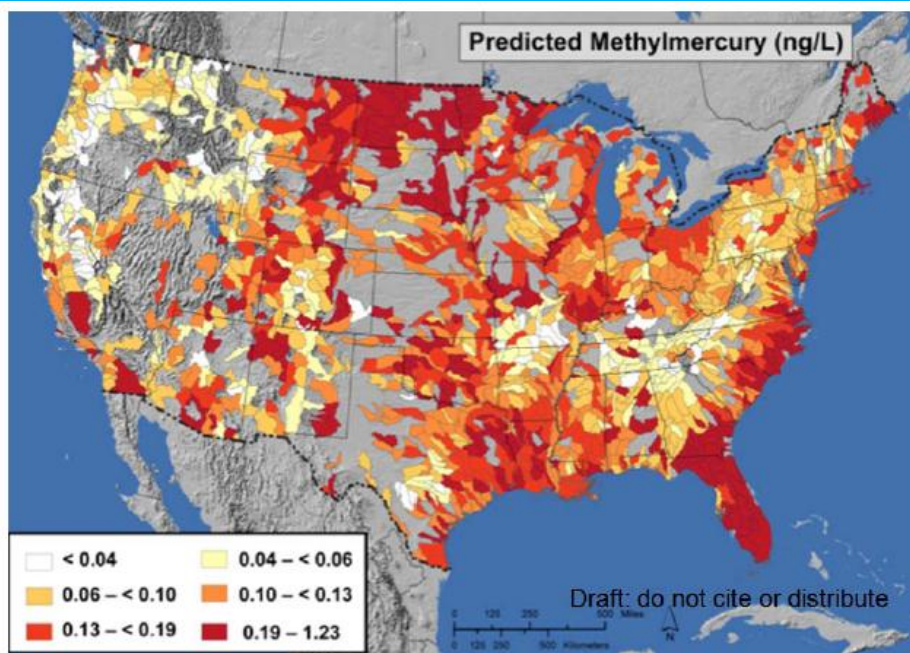
### Bacterial Sulfate Reduction



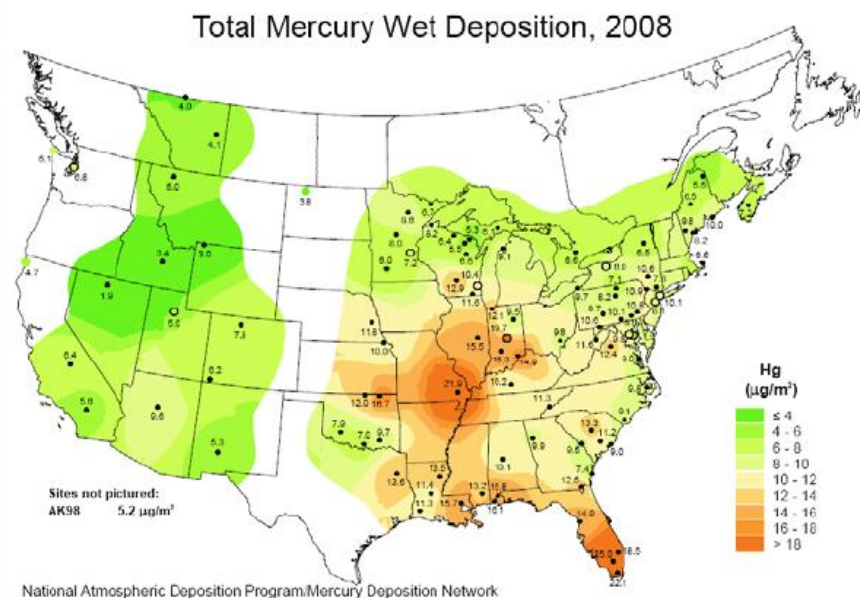
Bacterial sulfate reduction carried out by naturally-occurring sulfate reducing bacteria, is the main microbial process responsible for the production of highly neurotoxic and bioaccumulative methylmercury (MeHg).



# 7. Why is methylmercury especially problematic in the Everglades?



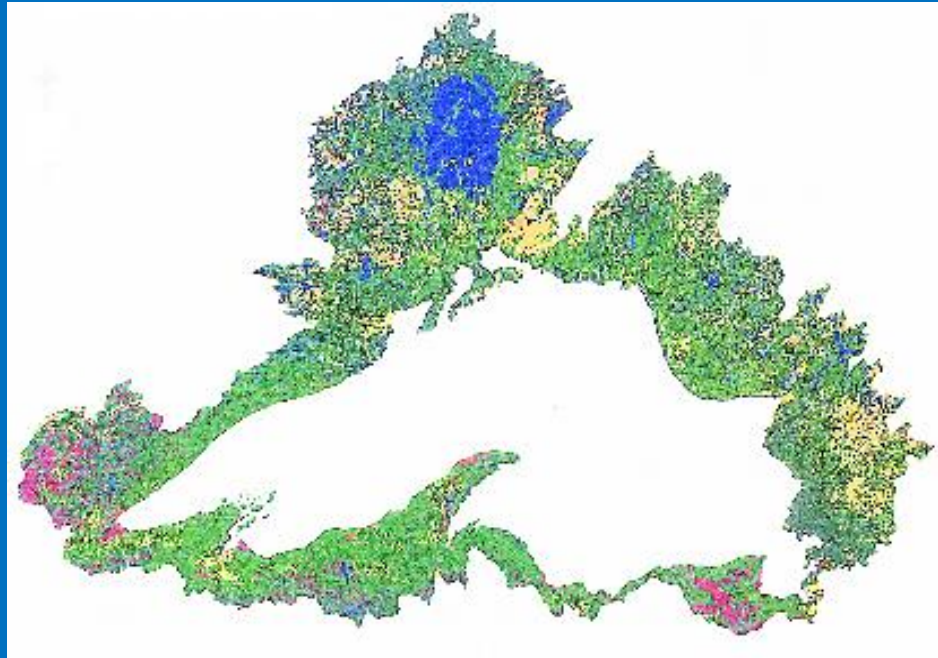
D. Krabbenhoft, N. Booth, M. Fienen, and M. Lutz - USGS  
and Tamara Saltman - USEPA, Nov. 2009,  
“A Methylmercury Prediction Tool  
for Surface Waters Across the United States”  
Methylmercury in fish in lakes and streams predicted  
based on pH, DOC, SO<sub>4</sub> and % wetland area in watersheds



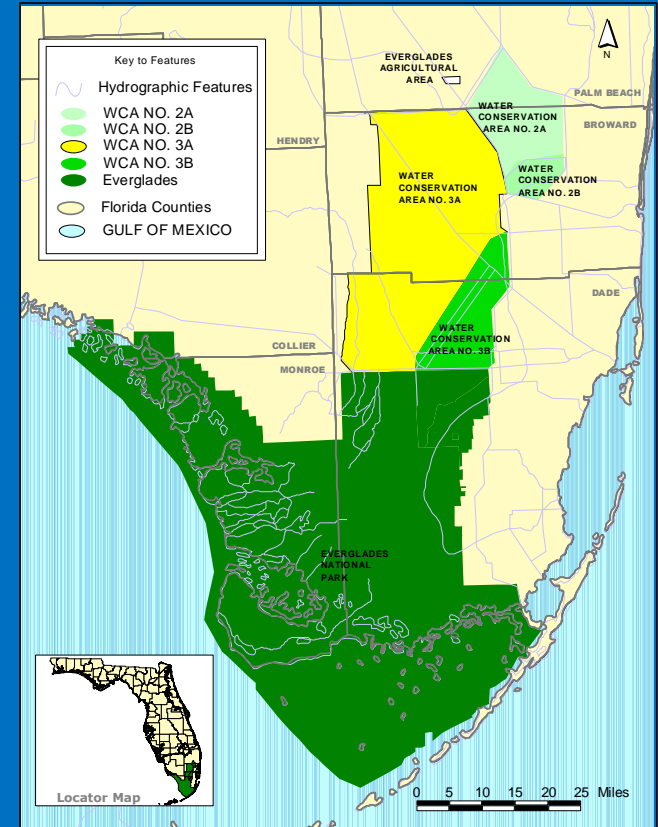
NADP Mercury Deposition Network, total mercury wet deposition, 2008  
<http://nadp.sws.uiuc.edu/mdn/>



# Mercury Vulnerability - Lake Superior vs. the Everglades



Vs.



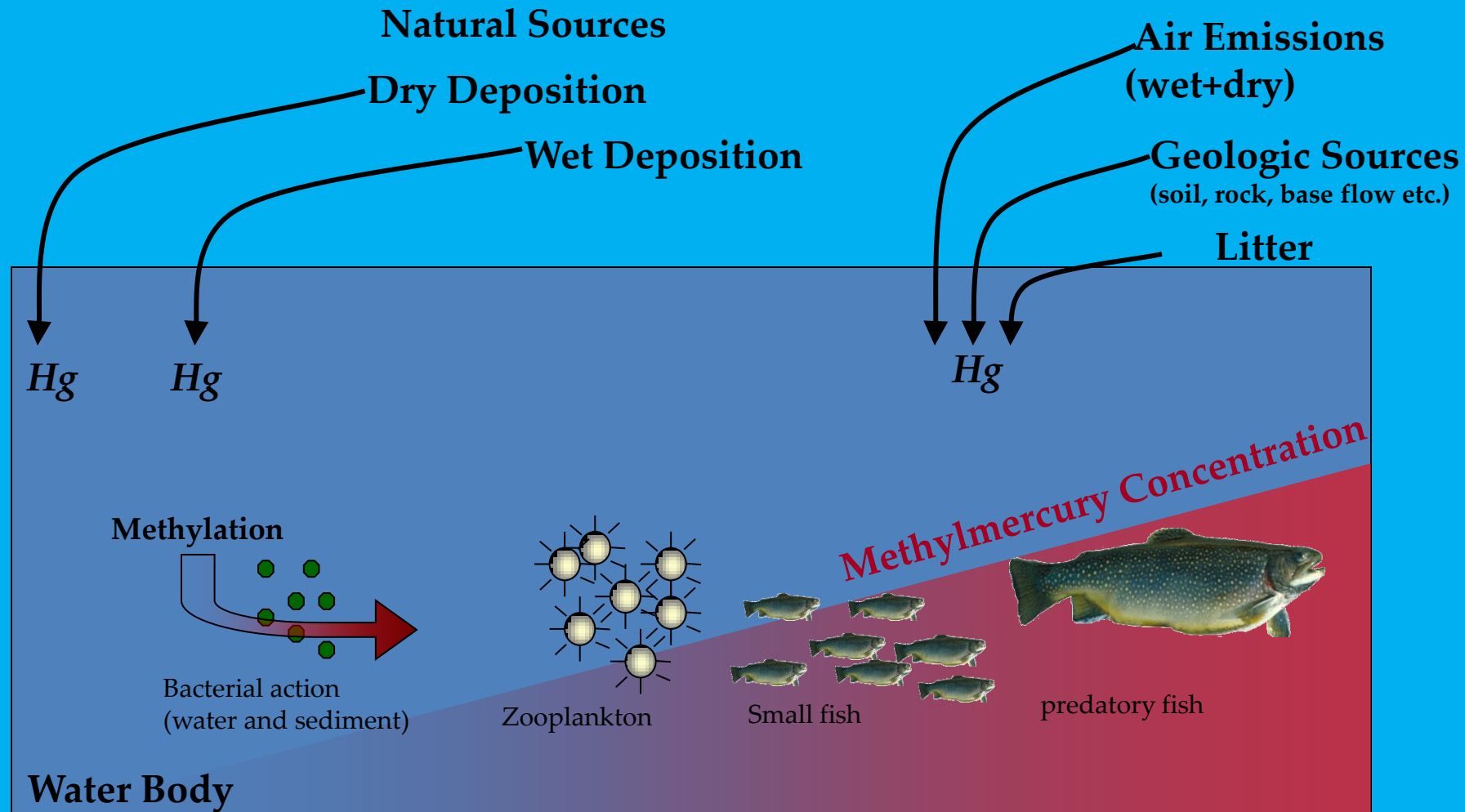
## Lake Superior:

- Cold
- Deep
- Low sulfate
- Low dissolved organic material

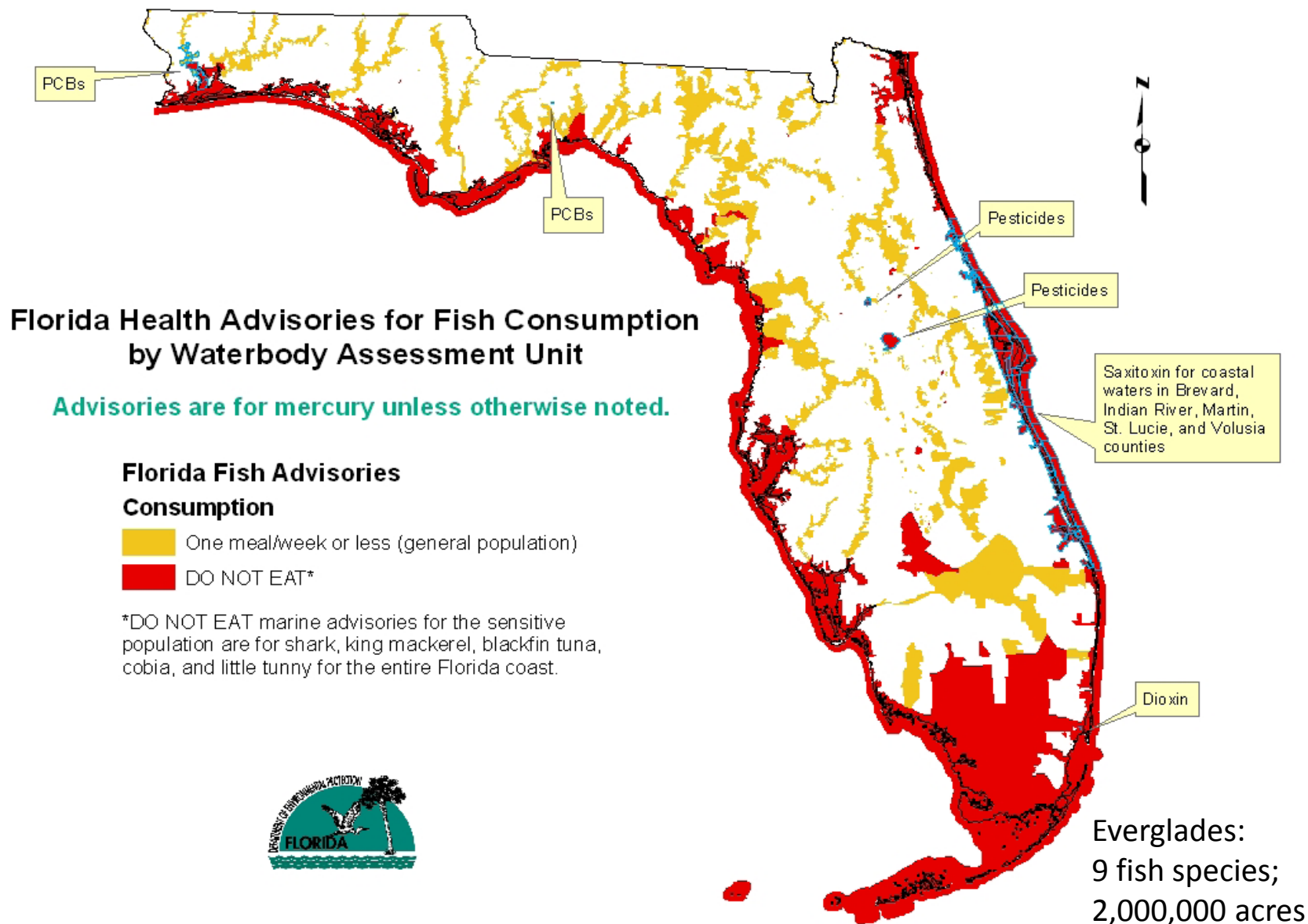
## Everglades:

- Hot
- Shallow
- High sulfate
- High dissolved organic material

## 8. How are Floridians and Florida wildlife exposed to MeHg?



# 9. Is our MeHg exposure problematic?



**Number of lake acres in the U.S.  
under fish consumption advisory for  
five frequently detected  
persistent and bioaccumulative contaminants**

<b>Contaminant</b>	<b>Lake Acres</b>
Mercury	16,800,000
PCBs	6,050,000
DDT	877,000
Chlordane	843,000
Dioxins	35,000

These five contaminants are responsible for 97% of advisories (2008).

USEPA 2008 Biennial National Listing of Fish Advisories.

<http://www.epa.gov/fishadvisories/advisories/tech2008.pdf>

*“The Everglades were not really set aside for any kind of geological wonders or scenic features. It’s the first national park set aside simply for its wildlife and the plants and trees - for its biological diversity.”*

President Harry Truman, Everglades National Park dedication, 1947.

## **MeHg Levels Protective of Fish-eating Wildlife (as MeHg in water)**

from the Mercury Study Report to Congress (1997)

<b><u>Wildlife spp.</u></b>	<b><u>MeHg (ng/l)</u></b>
Mink	0.057
River otter	0.042
Kingfisher	0.027
Loon	0.067
Osprey	0.067
Bald eagle	0.082
<b>Everglades*</b>	<b>0.210</b>

\*Everglades surface water, USEPA 2005 REMAP data, Scheidt and Kalla



# Everglades fish-eating birds and mercury

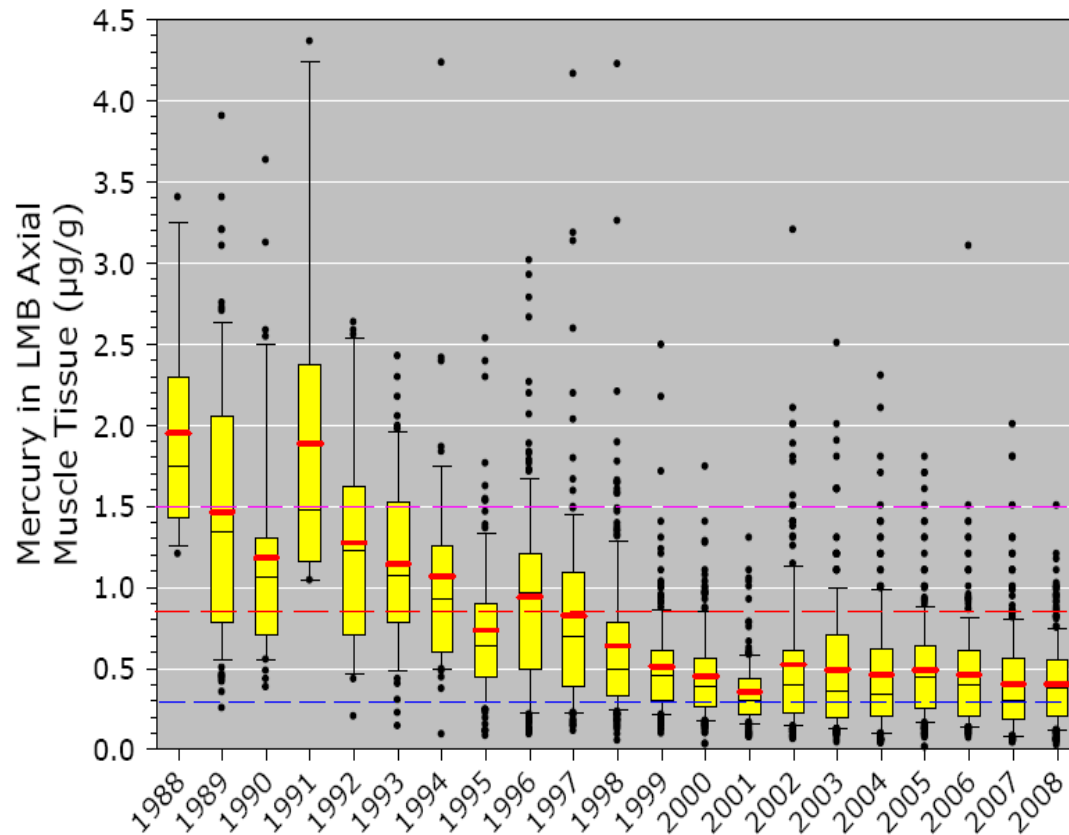
...all of the mercury-dosed (white ibis)... had significantly lower reproductive success than the control (undosed) group..., with up to 30% reduction in reproductive success.

The main loss of reproduction was due to nests not producing eggs, and this stemmed directly from a high rate of male-male pairings (up to 55 percent of males).....

....the lowest (mercury) effects level.... from this study is still commonly encountered by birds in the Greater Everglades today.

Peter Frederick (U of F), from the SFWMD,  
2010 South Florida Environmental Report, Vol. 1., Chapter 3B

# 10. Trends in mercury in Everglades fish



**BLACK LINE:** median

**RED LINE:** mean

**BOXES:** 25th and 75th percentiles

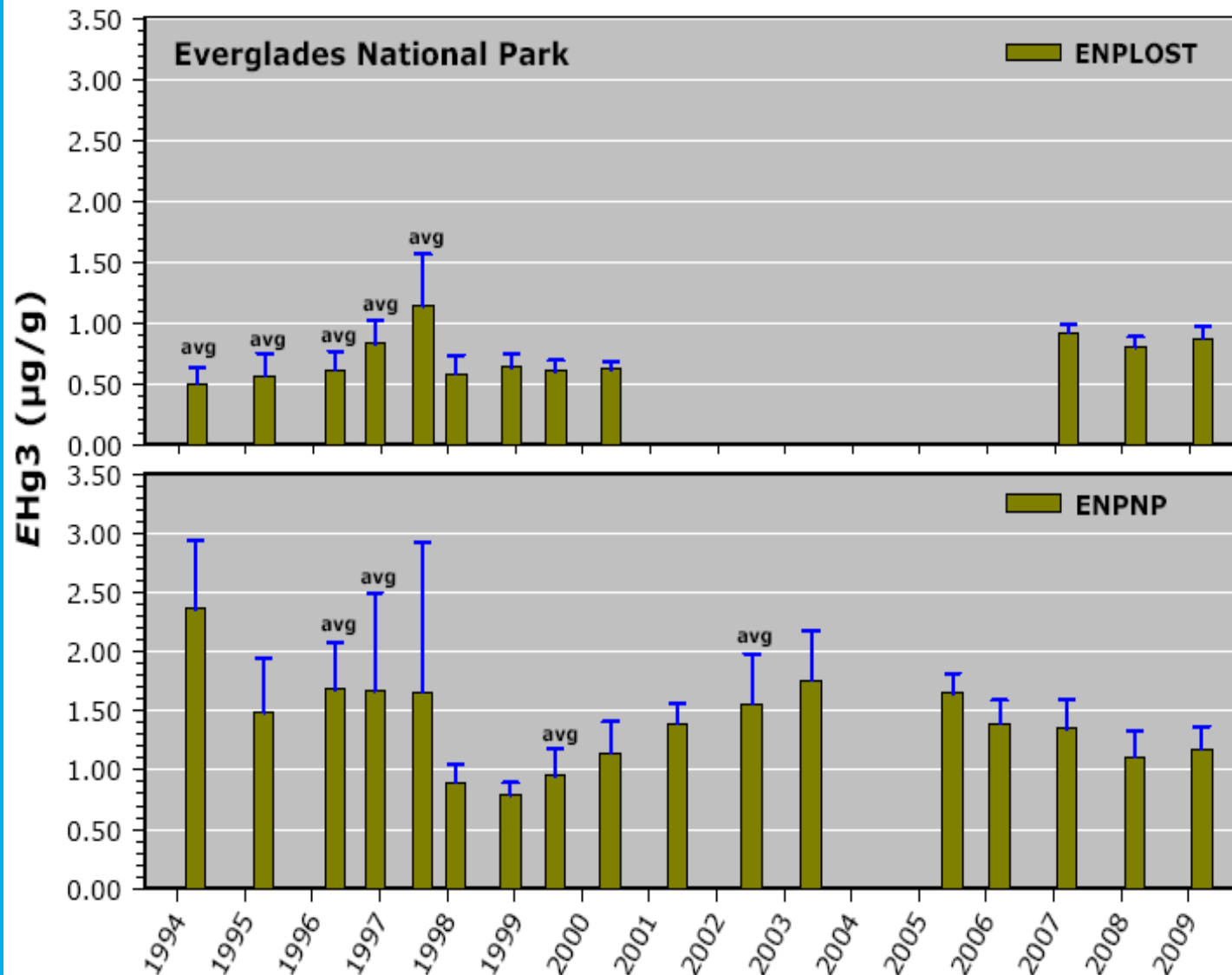
● **BLACK CIRCLES:** outliers

— **FLDOH Fish Criterion for "NO CONSUMPTION"**  
by general population (1.5 ppm)

— **FLDOH Fish Criterion for "NO CONSUMPTION"**  
by women of childbearing  
age and children (0.85 ppm)

— **USEPA Criterion for methyl-mercury in fish  
tissue (0.30 ppm)**

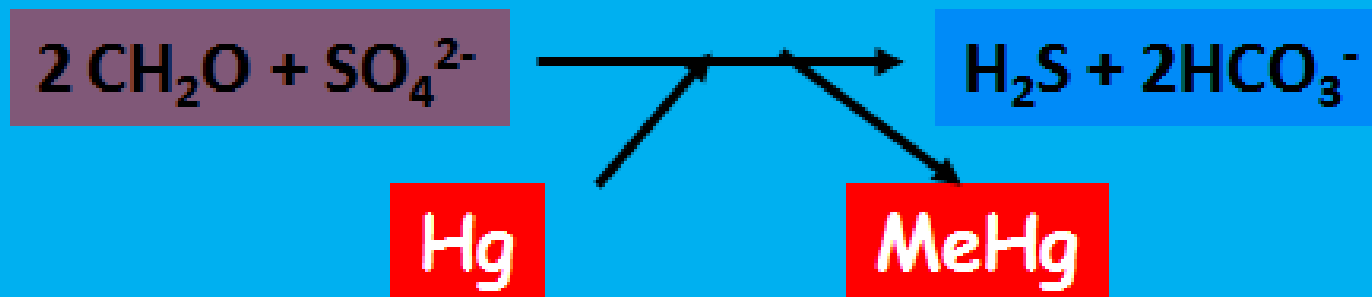
Mercury concentrations in ca. 3,000 largemouth bass (LMB) collected from Everglades Water Conservation Areas 1, 2, and 3 from 1988–2008 (T. Lange, FFWCC).



Mercury concentrations (EHg3) and 95% confidence intervals in age-standardized largemouth bass from the Everglades National Park, 1994-2009 (T. Lange, FFWCC).

# 11. Options for reducing Everglades mercury

## Bacterial Sulfate Reduction



Reduce either:

$\text{CH}_2\text{O}$  (Everglades plant material) - impractical;

$\text{Hg}$  (from atmospheric sources) - requires international cooperation; or,

$\text{SO}_4$  (from agricultural sources) - feasibility uncertain

## 12. Mercury Total Maximum Daily Load

TMDL (total maximum daily load):

The maximum amount of a pollutant that a water body can assimilate without exceeding water quality standards (safe levels of pollutants)

For MeHg in Everglades fish:

determine the existing MeHg concentration in fish,  
define a safe MeHg concentration in fish, and

1. calculate the percentage reduction in Hg atmospheric sources, or,
  2. the percentage reduction in SO<sub>4</sub> agricultural sources,
- necessary to reduce MeHg in fish to safe levels



**To achieve the TMDL via Hg source reduction,  
we need to determine how atmospheric Hg  
sources to the Everglades can be reduced so as to  
achieve safe MeHg levels in fish**

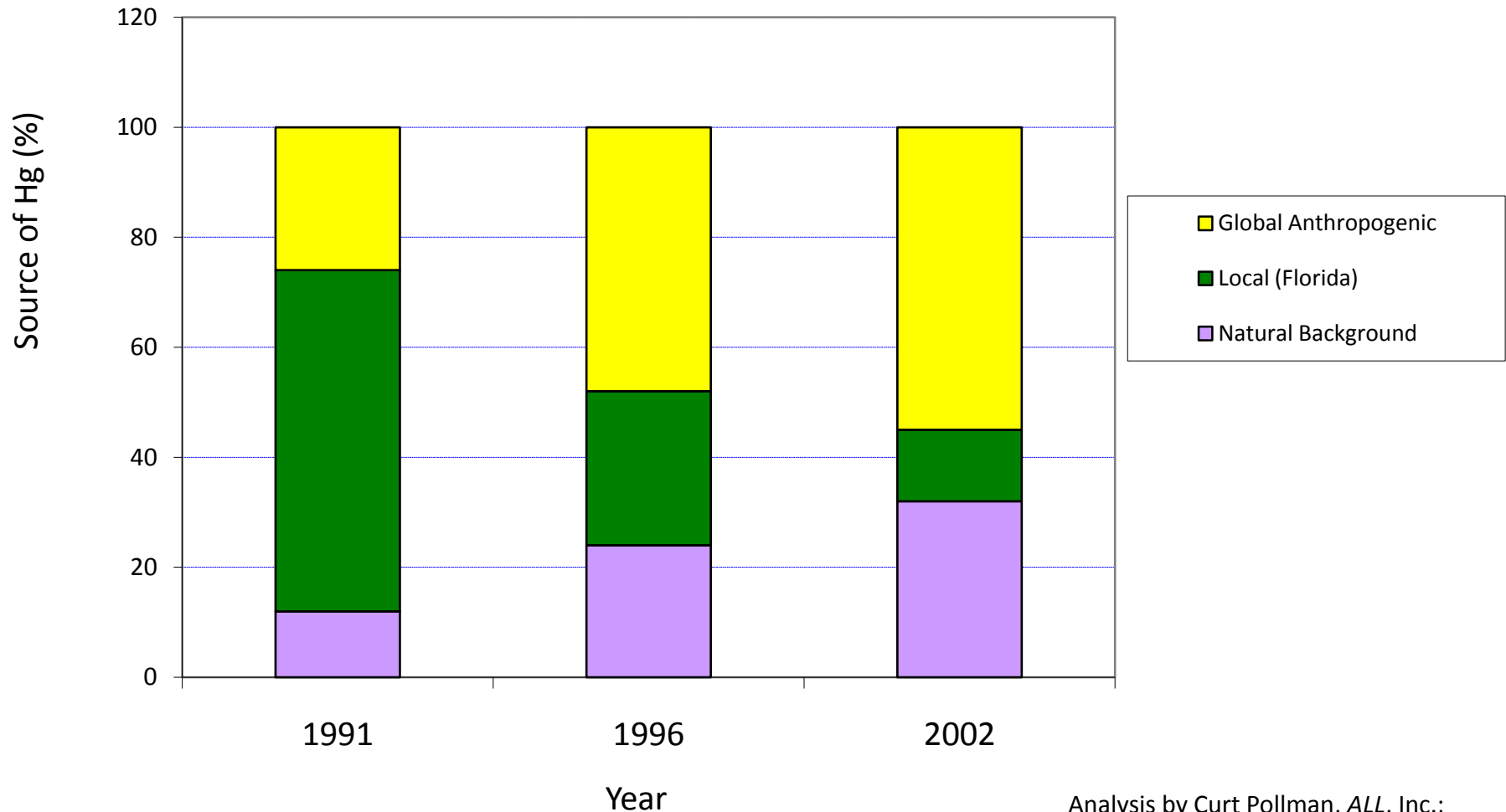
The primary air emissions of mercury in south Florida circa 1990 were incineration of municipal and medical wastes

Mercury emissions from incinerators have since declined by approximately 90%, primarily through pollution prevention activities

While in 1990 at the peak level of atmospheric mercury deposition, the majority of deposition to the Everglades originated from emission sources within south Florida;

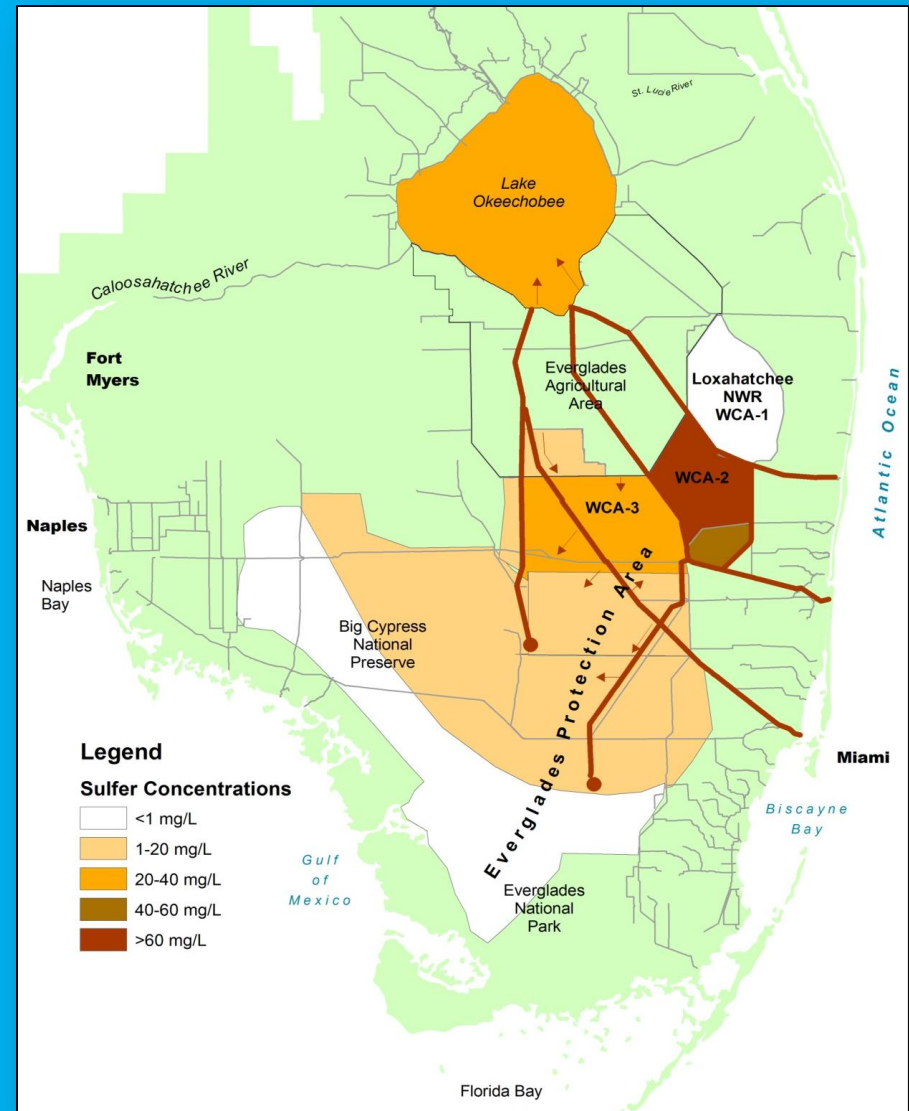
Presently, anthropogenic point source emissions of mercury from south Florida are a small fraction (<10%) of peak (1990) levels

# Reduction over time in the contribution of local (south Florida) atmospheric Hg emissions, to total atmospheric deposition of Hg to the Everglades



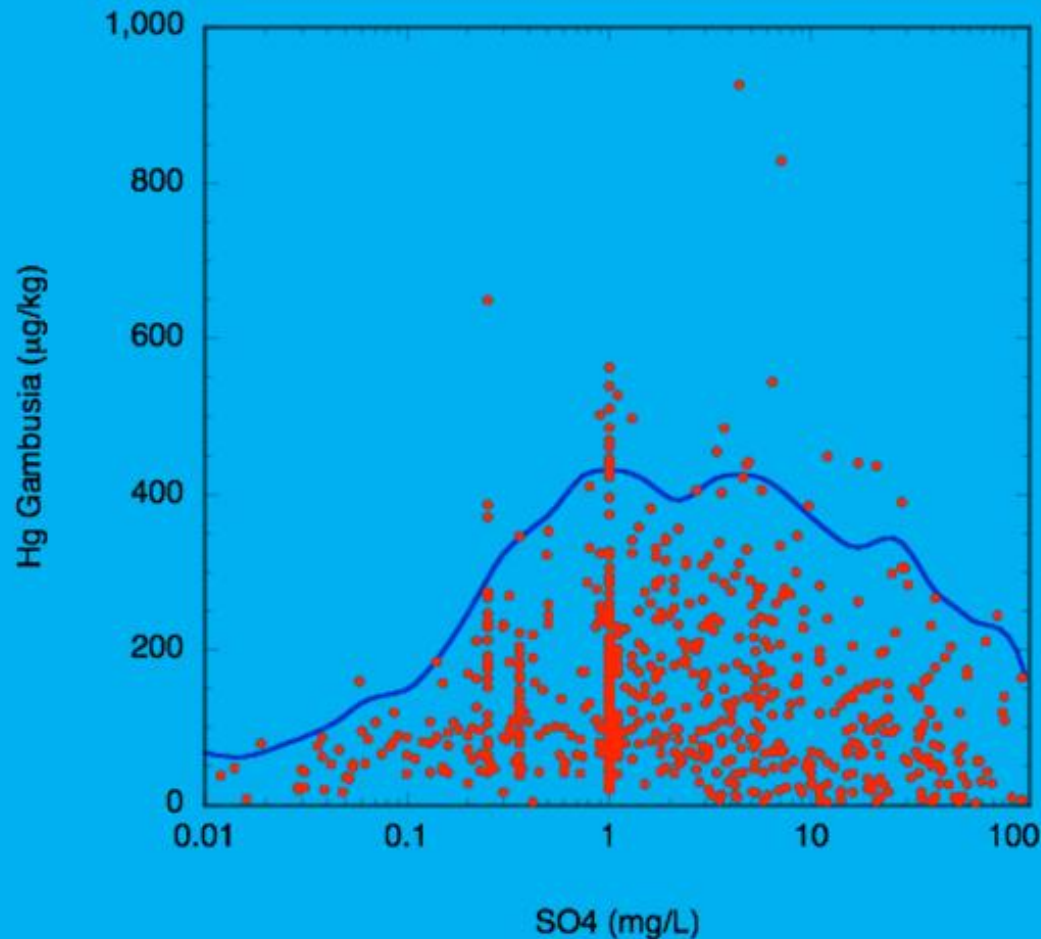
Analysis by Curt Pollman, *ALL*, Inc.;  
graphic by T.M. Chandrasekhar, FDEP

To achieve the Hg TMDL via  $\text{SO}_4$  source reduction, we need to determine if  $\text{SO}_4$  sources to the Everglades can be reduced so as to achieve safe MeHg levels in fish



Distribution of sulfate concentrations in surface waters of the Everglades. Sulfur is applied in the EAA to acidify soil and thus increase phosphorus and essential trace metal availability to crops.

# Information need: $\text{SO}_4$ relationship to Hg methylation rate - the “Goldilocks” zone



Mercury (Hg) in Everglades *Gambusia* (mosquitofish)  
plotted against surface water sulfate ( $\text{SO}_4$ )

(USEPA REMAP data, cycles 2-7, Scheidt and Kalla, USEPA; statistics by Pollman, *Aqua Lux Lucis*, Inc.)

# QUESTIONS?

## Everglades Mercury

1. Mercury: what is it?
2. How does Hg enter the environment?
3. How does mercury get into aquatic ecosystems?
4. Discovery of the Everglades mercury problem
5. How does mercury get into the Everglades?
6. How is mercury converted to methyl mercury (methylmercury)?
7. Why is methylmercury especially problematic in the Everglades?
8. How are Floridians and Florida wildlife exposed to methylmercury?
9. Is our methylmercury exposure problematic?
10. Trends in Everglades mercury in fish
11. Options for reducing Everglades mercury
12. Mercury total maximum daily load